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Status and potential of biogas energy from animal wastes in Turkey

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ABSTRACT

Biogas is a potentially important energy source that can be used for the production of heat, electricity and fuel. It can be produced at wastewater treatment plants, landfills, food and other industrial operations throughout the world. There is largely untapped potential in agricultural operations where animal waste is often land applied or otherwise disposal of without conversion to energy. According to the last agricultural census (2009) in Turkey; there are a total of 3,076,650 agricultural enterprises and approximately 70% of these enterprises are running livestock farming. 10,811,165 of total animal is cattle, 26,877,793 of total animal is small ruminant and 234,082,206 is poultry. The amount of wet waste of these animals is about 120,887,280 t. These wastes could be a major problem for enterprises and cannot be utilized properly. The best way to utilize waste is to produce biogas. In this study, biogas amount which will be obtained from animal waste was calculated for all provinces by using the number of livestock animals and also considering various criteria such as the rate of dry matter and availability. Animal origin waste map of Turkey was also produced with these calculated values. The biogas energy potential of Turkey was found to be 2,177,553,000 m^3 (2.18 Gm^3) by using the animal numbers in the last agricultural census (2009). The total biogas potential is originated from 68% cattle, 5% small ruminant and 27% poultry. Biogas energy equivalence of Turkey is approximately 49 PJ (1170.4 ktoe). When the prepared waste map is examined; provinces that have more than 1 GJ of biogas energy potential are found to be; Bolu, Balıkesir, İzmir, Sakarya, Konya, Manisa, Erzurum, Afyon, Kars and Ankara respectively.

Contents

1. Introduction

Energy consumption increases rapidly because of high economic development speed rate of Turkey. Energy need of Turkey will be doubled between 2000 and 2010 and five times bigger between 2000 and 2015. Biogas is seen as an important source of energy to meet the electricity demands for small towns and rural areas [1]. About 25% of the population provide living with agriculture, livestock and forestry in Turkey. Mostly, crop production is made along with animal husbandry. Existing socio-economic and geographical characteristics of Turkey have very significant potential suitable for all types of animal husbandry. In Turkey, having a share of 6% of GDP of animal husbandry is an important indicator of this [2]. As the development of agriculture and animal husbandry with population increase, animal waste potential also increases as well. However, it is not possible to say that the country utilize this potential in a rational and efficient manner [3].

Animal waste material is neither utilized and nor used as it is supposed to be even this big potential of animal waste in Turkey. This organic-based waste is either burned directly or spilled to the environment. A small portion of this is used as fertilizer in agricultural areas after being waited a long time in the open spaces. Lack of control of animal waste in an orderly manner and unconscious disposal of waste material to arable fields, pastures and rivers degrade soil structure as a result of contamination.

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Evaluation of existing animal waste biogas production potential of our country and promote the use of such wastes must be brought under control in terms of environmental health. Besides, the prevention of negative effects of animal waste disposal will be provided in obtaining fermented fertilizer for crop and energy production. In Turkey, in a year, almost 20 million tones of animal fertilizers are used as dried cow dung, which causes big economic losses [1]. If these burned-dried cow dungs are converted into biogas energy, villagers can provide their energy costs such as electricity and gas and because it is not used as dried cow dung, those will be used as fertilizers at farm.

In this study, the amount of biogas energy potential was determined for all provinces from the number of cattle, small ruminant and poultry by taking into account the various criteria. Potential waste map was also developed for Turkey.

2. Materials and methods

Turkey's land area 780,000 km^2 (78 million hectares) of arable land is the sum of 280,000 km^2 (28 million hectares) [4]. This corresponds 36% of the total land area. Field crops are grown in the majority of agricultural fields. Turkey's total number of agricultural holdings and characteristics are given in Table 1. According to agricultural census done in 2001, Turkey has a total of 3,076,650 agricultural holdings. While 67.43% of these enterprises make animal and vegetable production, 1.77% of them only makes animal production. So, in Turkey, approximately 70% of agricultural livestock enterprises are operating in [5]. According to the Turkish statistical institute (TUIK) in Turkey, raising the number of animals is given in Table 2 [6].

40.75% is hybrid, 34.44% is cattle culture, 24.00% is domestic cattle and 0.81% is composed of the buffalos out of 10,811,165 of cattle group. Domestic sheep has the largest share with the 77.10% of the small ruminant animals amongst the 26,877,793. This is followed by 18.53% goats, 3.82% and 0.55% merinos sheep and angora goats respectively. In poultry, 69.83% is chicken meat, 28.41% is laying hens, 1.18% is turkeys, 0.40% is duck and 0.18% is goose for a total of 234,082,206 pieces.

The total number of cattle, small ruminants and poultry were determined using TUIK data for 81 provinces in Turkey. These numbers were then used to calculate the amount of animal waste for all the provinces. There are many factors which effect the amount of waste and biogas obtainable in the livestock operations. These are the type of animal, body weight, value of the ratio of total solids, volatile solids ratio, the availability of waste and biogas yields. Several of these factors are taken from the literature values are given in Table 3.

Table 1
The number of agricultural holdings of Turkey [5].

Characteristics of agricultural holdings	Number	%
Animal production	54,523	1.77
Animal + crop production	2,074,439	67.43
Crop production	929,582	30.21
Fisheries and hunting holdings	18,106	0.59
Total	3,076,650	100.00

Table 2
Raising the number of animals in Turkey [19].

Animal type	Number of animals (number)
Cattle	10,811,165
Small ruminants	26,877,793
Livestock	234,082,206

In calculation of the amount of waste, 10–20 kg/day (wet) waste yield can be considered for the cattle, 5% and 6% of body weight per day may be based on the amount of waste. In the same way, 2 kg (wet)/day or 4–5% body weight per day can be considered as waste production for sheep and goat. Daily waste production for chicken production is 0.08–0.1 kg (wet)/day or 3–4% of the body weight [7].

Values given in Table 3 are used in determining the amount of waste that can be obtained from animals. Body weight was taken as 400 kg for cattle, 50 kg for small ruminants and 2 kg for poultry. Daily amount of wet waste, as a percentage of body weight is chosen as 5% for cattle, 4% for small ruminants and 5% for poultry. According to these values, daily amounts of wet waste are taken into account as 20 kg for cattle/day, 2 kg/day for small ruminant and 0.1 kg for poultry/day. Wet waste quantities of cattle, small ruminants and poultry are calculated separately and then by adding these values, the total amount of animal waste for each province are established.

Having 8–13% of TK of the feeding material is suitable for the production of biogas. It is subjected to deposit of solids in material when the solid content is too low. It is encountered that gas output is to be blocked if this rate is much higher [8]. Solid rates are around 5–25% of cattle manure, 10–90% of chicken manure and 30% of sheep manure. In case of using excess water during the collection of animal waste may fall to TK up to 2–5%. This makes system less efficient during heating water due to high energy consumption [9].

Quantities of waste in animal wastes vary according to animal nutrition regime and size and also climatic conditions. In addition, the amount of waste obtained according to the breeding type varies. Obtained waste should be calculated as 50% of the total waste if animals are kept tied only at night [10]. Staying time of the animals in the barn is 65% for dairy cattle, 25% for beef cattle, 99% for poultry and 13% for small ruminants [11,12].

3. Results and discussion

Wet waste per day according to the number of animals and animals in designated provinces in Turkey in 2009 with a map showing the values of the total waste is given in Fig. 1. When the map is examined, the regions with high potential for waste are concentrated in Eastern Anatolia Region for cattle farming, Aegean and Central Anatolian Regions for poultry.

There are three provinces that have the potential of 4 million t year^{-1} waste when the total amount of wet waste of provinces is examined. These are: Balıkesir, Erzurum and Konya. The provinces that have the potential of 3–4 million t year^{-1} waste are Izmir, Van and Kars. Afyon, Şanlıurfa, Ağrı, Bolu, Manisa, Ankara, Aydın, Samsun, Sivas, Diyarbakır and Muş are the provinces that have the potential of 2–3 million t year^{-1} waste. Provinces that have the potential of 1.2 million t year^{-1} of animal waste are given in Table 4 depending on the animal type.

Looking at the distribution of 120,887,280 t year^{-1} wet animal waste by type of animal waste are 82% of cattle, 11% sheep and 7% poultry origin in Turkey. When provinces with wet waste amount is over 3 million t year^{-1} is examined; it is seen that intensive cattle breeding is undertaken in these provinces. 71% of the total waste is from cattle, 12% of it is from small ruminant and 17% is from poultry in Balıkesir province that has the potential of 4.7 million tons of wet waste. In the same way, the amount of cattle waste is 93% in Erzurum, 70% in Konya, 75% in Izmir, 93% in Kars and 42% in Van. The animal waste rate is 58% in total waste in Van province due to more intensive farming of small ruminants. Small ruminant animal waste is 61% in the total animal waste in the provinces of Sanliurfa that small animal farming is most intense. Poultry waste ratio is 63% in Bolu province and 50% in Sakarya province where intensive poultry is undertaken.

Table 3
Waste properties and biogas yields by type of animal [7,12,19–22].

Animal type	Body weight (kg)	Wet waste amount		TK (%)	UK (%)	Using	Biogas yieldl/kg UK
		% of weight	kg day^{-1}			Staying time in the barn (%)	
Cattle	135–800	5–6	10–20	5–25	75–85	Milk 65 Meat 25	200–350
Small ruminant	30–75	4–5	2	30	20	13	100–310
Poultry– egg	1.5–2.0	3–5	0.08–0.1	10–35	70–75	99	310–620
Poultry – meat				50–90	60–80		550–650



Fig. 1. Distributions of waste amount potential of animal origin by province in Turkey.

Table 4
The total wet animal's waste values of provinces in Turkey according to the data in 2009.

Province	Wet waste potential						
	Cattle		Small ruminants		Poultry		Total
	t year^{-1}	%	t year^{-1}	%	t year^{-1}	%	t year^{-1}
Turkey	98,496,753	82	13,846,527	11	8,544,001	7	120,887,280
Balıkesir	3,329,377	71	547,047	12	801,945	17	4,678,369
Erzurum	3,886,987	93	293,939	7	9315	0	4,190,241
Konya	2,914,868	70	910,306	22	312,555	8	4,137,729
İzmir	2,689,116	75	379,268	11	522,941	14	3,591,325
Kars	2,941,659	93	203,504	6	10,869	1	3,156,032
Van	1,274,668	42	1,789,287	58	9994	0	3,073,949
Afyon	2,075,726	73	465,098	16	309,176	11	2,850,000
Şanlıurfa	1,078,838	38	1,734,014	61	35,644	1	2,848,496
Ağrı	1,845,988	72	714,742	28	6174	0	2,566,904
Bolu	826,375	34	71,709	3	1,563,485	63	2,461,569
Manisa	1,338,382	57	396,007	17	618,042	26	2,352,431
Ankara	1,594,130	69	464,933	20	249,766	11	2,308,829
Aydın	2,073,602	91	105,549	5	86,201	4	2,265,352
Samsun	2,079,033	93	93,143	4	72,327	3	2,244,503
Sivas	1,871,333	89	204,891	10	14,955	1	2,091,179
Diyarbakır	1,615,497	78	446,912	21	18,019	1	2,080,428
Muş	1,501,756	74	499,425	25	16,965	1	2,018,146
Kayseri	1,649,493	82	244,459	12	114,656	6	2,008,608
Kırşehir	1,842,542	94	91,249	5	10,672	1	1,944,563
Sakarya	916,449	49	24,840	1	921,322	50	1,862,611
Kastamonu	1,774,710	96	51,450	3	12,014	1	1,838,174
Çanakkale	1,247,147	70	396,380	22	144,213	8	1,787,740
Tokat	1,618,804	92	131,988	7	14,790	1	1,765,582
Yozgat	1,419,310	86	188,365	11	40,677	3	1,648,352
Bursa	1,090,102	72	214,484	14	214,332	14	1,518,918
Denizli	1,171,592	79	225,269	15	89,071	6	1,485,932
Çorum	1,259,710	86	75,406	5	136,053	9	1,471,169
Mersin	660,103	54	357,196	29	211,310	17	1,228,609

Table 5
Available animal waste biogas potential values of provinces in Turkey according to data in 2009.

Province	Biogas potential							Heating value (GJ/year)
	Cattle		Small ruminants		Poultry		Total (1000 m^3/year)	
	1000 m^3/year	%	1000 m^3/year	%	1000 m^3/year	%		
Türkiye	1,477,451	68	108,003	5	592,099	27	2,177,553	49,430,453
Bolu	12,396	11	559	0	108,350	89	121,305	2,753,623
Balıkesir	49,941	45	4267	4	55,575	51	109,783	2,492,074
İzmir	40,337	51	2958	4	36,240	45	79,535	1,805,444
Sakarya	13,747	18	194	0	63,848	82	77,789	1,765,810
Konya	43,723	60	7100	10	21,661	30	72,484	1,645,387
Manisa	20,076	30	3089	5	42,830	65	65,995	1,498,086
Erzurum	58,305	95	2293	4	646	1	61,244	1,390,239
Afyon	31,136	56	3628	6	21,426	38	56,190	1,275,513
Kars	44,125	95	1587	3	753	2	46,465	1,054755
Ankara	23,912	53	3627	8	17,309	39	44,848	1,018,050
Aydın	31,104	82	823	2	5974	16	37,901	860,353
Samsun	31,185	84	727	2	5012	14	36,924	838,175
Kayseri	24,742	71	1906	6	7946	23	34,594	785,284
Van	19,120	57	13,956	41	693	2	33,769	766,556
Ağrı	27,690	82	5575	17	428	1	33,693	764,831
Bursa	16,352	50	1673	5	14,853	45	32,878	746,331
Şanlıurfa	16,183	50	13,525	42	2470	8	32,178	730,441
Çanakkale	18,707	59	3092	10	9994	31	31,793	721,701
Sivas	28,070	91	1598	5	1036	4	30,704	696,981
Kırşehir	27,638	95	712	2	740	3	29,090	660,343
Diyarbakır	24,232	84	3486	12	1249	4	28,967	657,551
Çorum	18,896	65	588	2	9429	33	28,913	656,325
Kastamonu	26,621	96	401	1	835	3	27,857	632,354
Muş	22,526	82	3896	14	1176	4	27,598	626,475
Mersin	9902	36	2786	10	14,644	54	27,332	620,436
Tokat	24,282	92	1030	4	1025	4	26,337	597,850
Yozgat	21,290	83	1469	6	2819	11	25,578	580,621
Denizli	17,574	69	1757	7	6173	24	25,504	578,941

Availability of waste (useable) and the rate of dry matter of the waste must be taken into account in determining the biogas potential from animal wastes. The availability of waste was selected 50% for cattle, 13% for small ruminants, 99% for poultry from Table 3 by taking into account the residence time in the barn. Rates of solid waste for cattle is taken 0.15, for small ruminant is 0.30 and for poultry is 0.35 respectively and the amount of biogas is 200 m^3 obtained from 1 ton of solid animal waste and biogas heating value was adopted as 22.7 MJ/m^3 [11,12]. Animal waste biogas potential values of provinces in Turkey are given in Table 5 by using the values given above.

The calculated Turkey's biogas potential is about 2 177,553,000 m^3 (2.18 Gm^3) by using animal numbers of TUIK in 2009. 68% of total biogas potential is cattle origin, 5% small ruminant and 27% of poultry origin. The potential of biogas energy equivalent of Turkey is about 49 PJ (1170.4 ktoe).

Similar works that were carried out in this area indicate 3302.85 million m^3 gross biogas potential and 2350 ktoe (ton petroleum equivalent) from animal wastes in Turkey [5,7].

Ranking of the provinces according to the wet waste potential has changed when the animal waste biogas potential is calculated by taking into account the availability and rates of solid material. Bolu province has the highest potential for biogas with 121 Mm^3/year. 11% of the potential of Bolu province is cattle and 89% of the poultry origin. Bolu is province where poultry meat is most intensively produced. Balıkesir, Izmir, Sakarya, Konya, Manisa, Erzurum, Afyon, Kars and Ankara have been following Bolu respectively. These provinces have the potential of biogas over 40 Mm^3/year. Erzurum and Kars are the provinces for intensive cattle breeding, Sakarya and Manisa are provinces of intensive poultry farming. In Balikesir, Izmir, Konya, Afyon and Ankara as well as cattle and poultry production is carried out intensively. The potential for biogas is 34 Mm^3/year in Van and 32 Mm^3/year in Sanlıurfa that the intensive farming of small ruminants breeding is being made.

4. Conclusions

Animal origin waste map is developed for Turkey from the waste amounts for each province. The calculated animal origin wet waste amount is about 120,887,280 ton/year for Turkey. The amount of obtainable biogas is 2.18 Gm^3 from these wastes and energy equivalence is calculated as 49 PJ (1170.4 ktoe) by taking into account the rates of sediment and usability of animal waste by animal type.

Biomass energy potential of Turkey is reported to be; 120 Mtoe as natural capacity, 50 Mtoe as technical capacity and 32 Mtoe as economic potential [13]. Biomass energy supply including wastes has been 7208 ktoe in 1990, 7068 ktoe in 1995 and 6457 ktoe in 2000 [14]. The existing classical and modern biomass energy production which was planned in Turkey for 2010 is about 7414 ktoe, for 2020 is 7520 ktoe and for 2030 is 8205 ktoe [13]. When the so-called classic wood biomass is not taken into account, animal wastes have a significant share in modern biomass potential.

When the waste map and obtainable biogas values are examined, Bolu, Balıkesir, İzmir, Sakarya, Konya, Manisa, Erzurum, Afyon, Kars ve Ankara are the provinces which have the potential of biogas over 1 PJ. Most of these provinces are involved with intensive poultry farming. Poultry sector is a rapidly developing sector in Turkey unlike other animals husbandry sector. This development took place faster than the average of the world clearly demonstrates the success of the sector. One of the biggest problems of this sector is the difficulty to eliminate waste disposal. The random storage of wastes in poultry farming close to residential areas causes environmental pollution and odor problem and also affects biosafety. When considering energy requirement in animal husbandry sector and environmental problems caused by animal wastes, a solution for both problems was the establishment of biogas plants. By this way, an available structure for waste disposal and energy production from animal wastes will be provided.

Burning of biogas provide hot water and air in cooking stoves. Heat and power from burning biogas can also be used in the production of lighting. The main output material obtained from biogas plant is the fertilizer with organic content. This treated fermented fertilizer is free from plant pathogens. Anaerobic fermentation of biogas from animal wastes and fermented manure provides renewable energy production and usage. This will reduce the amount of environmentally hazardous waste and waste management costs.

Considering economic point of view, biogas seems to be an expensive source of alternative energy systems due to high initial investment costs. Small-scale biogas plants could pay for itself approximately 8–10 months when it is operated efficiently [15]. However, a payback period of 5 years for a biogas plant that produces 500 kW of electricity when cattle manure is used as a raw material and a payback period of 8.5 years for plant with a capacity of 500 kW of electricity when cattle-chicken manure is used are reported [16]. However, a financing is needed in the first place for the establishment of facility. This funding can be provided with government-backed loan or a foreign private investor. In many countries, the programs initiated considering environmental and health benefits of biogas technology. Incentives and credits can be applied to reduce the cost and expand biogas systems.

Taking into account climatic conditions and production facilities; designing biogas systems for low investment costs, high efficiency and easy installation, operation and maintenance will enable the development of biogas technology in Turkey. Poultry sector with increasingly integrated facilities in particular is needed to invest for recovering these wastes economically.

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